Notebook, N-07-08-12

07-08-12

Sodr. = 1953.

"Edison Effect."

Definition.

Phenomenon of flow of current observed in an ordinary incandescent lamp when a third electrode, which has been sealed in the lamp, is connected to the positive leading-in wire of lamp.

In the following experiments the effect will be observed by means of a D'Arsonval galvanometer reflecting a beam of light onto a straight scale at a distance of 53 inches.

August 13, 1907.

Sample 1.

Sample is marked for 110 V.
At this voltage it takes
570 milliamperes and there-
fore consumes .570 X 110 = 64 Watts
Assuming an efficiency of
3.4 watts per C.P. the lamp
is found to have approximately
19 Candle-Power.
Filament makes only one
loop and a platinum wire
is sealed in between the
filament terminals. This
third electrode extends into
the vacuum about 1/4 inches.
Took off readings with gal.
connected between Pt and positive

87.9	V. at Lamp	369	Amps.	2 mm Def.
89.3	"	409	"	7 "
93.7	"	431	"	15 "
95.1	"	447	"	21 "
100.7	"	474	"	48 "
103.1	"	492	"	76 "
109.6	"	537	"	109 "
112.7	"	550	"	772 "

I notice that the current from the aluminum, from the third electrode to the negative, does not appear immediately upon closing the lamp circuit but comes about one second later. This is not due to inertia in the galvanometer as this instrument will respond immediately to the slightest impulses.

August 14.1907.

Samp^e 1.
Carbon Filament. 116 V.
Gal between third electrode and Positive.
$\frac{1}{9}$ and $\frac{1}{77}$ Gal. shunt coils in.

Volts.	Amps.	MM. DEF.	
84.7	.398	1.5	Test "2.
95.1	.440	7	
101.9	.481	18.5	
107.5	.516	41	
110.5	.535	59	
117	.579	121	
120.5	.600	157	
128	.650	312	
131.2	.670	367	
142.2	.742	620	

Gal between third electrode and negative, and shunted as before —

142.2	.742	10

8/14/07.

Samp #1.
Carbon Filament. 116 V.
A 150 volt Weston Voltmeter used as Gal. = Connected between third electrode and positive.

Volts	Amps.	DEF.	
97.7	472	.1	Test #3.
117.5	549	1.1	
126.7	639	4	
140	728	8.9	
132.7	677	6	
146.7	770	10.3	

Samp was allowed to cool off and test was then repeated -

96.8	452	.1	Test #4.
117.7	550	.9	
119.7	593	1.8	
122.2	613	2.7	
131.7	672	4.8	
132.9	690	5.9	
145	767	9.3	
148	785	10	

(See Over)

August 15, 1907.

Lamp # 1.

Carbon Filament. 116 V.

Observations made with a Weston 150 V. Voltmeter, connected between third electrode and positive.

This is a repetition of last night's tests on the same lamp.

Volts	Amps.	Dec.	
95.8	442	.1	Test # 5
110	532	.6	
119	589	1.6	
126.7	640	3.1	
130.6	664	4.3	
141.5	737	8.5	
148	780	9.9	

8/15/07.

Samp# 1.
Carbon Filament. 116 V.
D'Arsonval Gal. between third electrode and positive.
Gal. shunted with the $\frac{1}{9}$ and $\frac{1}{99}$ coils in parallel.

Volts.	Amps.	Meter.	
87.6	395	1.5	Test #6.
95.1	440	.5	
99.9	467	.9	
103.3	491	1.6	
109	527	3.5	
113.7	553	5.7	
120	597	12.0	
123.4	620	15.5	
127	641	22.0	
131.8	674	31.5	
136	701	40.6	
138.3	719	44.7	
140	729	50.0	
145	760	58.5	
Gal between 3rd electrode and negative -			
146	770	7.0	

8/15/07.

Lamp #2.

Carbon Filament. 113½ V.

Takes .576 amps at rated voltage.

113.5 x .576 = 65.39 watts.

Opl. between 3rd electrode and positive ½ and ½ almost coats in 11.

Volts	Amps.	MM Def.	
85.3	397	15	Test #1.
91.8	434	5	
97.8	472	13	
103	509	30	
111	560	88	
114.1	581	130	
122	633	293	
126	663	417	
134.7	718	636	
Opl between 3rd electrode and negative			
134.7	718	0	

8/15/07.

Sample #2.
Carbon Filament. 113½ V.
Galvanometer between third electrode and positive.
$\frac{1}{9}$ and $\frac{1}{99}$ Gal. shunt coils in ll.
Repetition of Test #1.

Volts	Amps	MM Def.	
91.9	437	4	Test #2.
96.8	467	10	
100.4	491	18.	
103	508	26	
105	540	53	
117.2	569	90	
117.7	602	166	
119.3	618	203	
122.5	638	265	
130.7	693	487	
135	722	605	
Gal. between 3rd electrode + negative.			
135	722	3	

8/15/07.

Samp# 7.
Carbon Filament. 113½ V.
150 V. Weston Voltmeter between third electrode and positive.

Volts.	Amps.	Def.	
89.9	473	+	Test #3.
100	490	.2	
109.8	543	.8	
117.2	569	1.2	
119.3	617	3	
122.2	636	3.9	
131	697	7.2	
134	713	8.8	
136.7	732	10.1	
138.2	748	11	
145	793	13.2	

8/15/07.

Sample #2.
Carbon Filament. 113 ± V.
150 V. Weston Voltmeter between
Hind electrode and positive.
Repetition of Test #3.

Volts.	Amps.	Def.	
92.8	441	+	Test #4.
98.7	480	.1	
110.7	557	1.	
114.2	583	1.5	
119.8	619	3	
124.3	650	4.2	
128.7	680	6.	
131.3	699	7.1	
134.6	719	8.9	
142.2	770	12.1	
145.2	795	12.8	

The amount of current which flows thru the vacuum is very small - 3 of a 500 milampere meter be substituted for the galvanometer, it will not be affected appreciably with the lamps burning at 110 volts. This means that the current is less than .001 amp.

D.A.T. says that he has gotten enough current in this way to operate an ordinary telegraph sounder.

I am of the opinion that this large flow of current was due to residual mercury vapor in the lamps, as they were exhausted in the old way by means of 3 sprengel pumps.

The present lamps under test were not exhausted by mercury pumps.

August 14, 1907.

Sample #7.
Carbon Filament. 113½ V.
Galvanometer between third electrode and positive.
1/9 and 1/99 shunt coils in ||.
Second Repetition of Test #1.

Volts.	Amps.	MM. Def.	
89.8	.421	2	Test #5.
94.1	.450	4	
101	.497	14	
106.7	.537	30	
110.3	.557	50	
113.9	.579	80	
119	.617	141	
124.2	.651	232	
133.2	.711	470	
136	.732	538	
142.7	.780	610	
Gal. between 3rd electrode + negative -			
142.7	.780	18	

The third electrode in this lamp is not all platinum. It is platinum for a short distance at the base but consists mostly of a black substance resembling carbon filament which is emitted onto the platinum.

8/16/07.

Sample #3.

Tungsten Filament.

Lamp is not marked but seems to be about the right brilliancy at 10 volts. It takes about 5.1 amperes at this P.D.

Galvanometer connected between third electrode and positive and is not shunted.

Current readings could not be taken accurately because meter was calibrated for 100 amps.

Volts.	Amps.	MM Def.	
4.01	3	15	Test #1
5.12	3.4	1	
6.14	4	5.5	
7.43	4.3	76	
8.09	4.6	45	
8.75	4.9	69	
9.27	5	85	
10.14	5.2	114	
11.2	5.6	148	
13.07	6.1	221	
13.62	6.3	240	
14.95	6.6	280	
"	"	0	- Gal. Int. 3rd + neg. electrode

The galvanometer has been moved, since the last test and when setting up again I changed the distance from the galvanometer mirror to the scale. Before it was 53 in. and now it is 48 in. The change was made so as to get a sharper image of the beam of light.

September 11, 1920.

Irradiation Experiment, Sample #3. Galvanometer connected between third electrode and positive and is not shunted. Have no suitable meter for taking current readings.

Test #2.

Volts	MM. Def. = Amps. X 10^7
6.30	5
6.99	10.5
7.61	27
8.30	44
9.00	62.5
9.70	79
10.4	95.5
11.1	112
12	133
13	161
13.98	197
15	249

1	
20	
52	
85	
121	
152	
184	
216	
259	
311	
380	
480	

Gal. between 3rd electrode and negative –

15	0.

September 12, 1907.

Calibration of Galvanometer

Resistance of Gal. = 252 Ω.
Shunted it with 1 Ω and connected in series with a 500 milliampere meter.
Readings as follows –

.005	amps.	=	107 mm. deff
.010	"	=	214 "
.015	"	=	315 "
.020	"	=	405 "
.025	"	=	516 "
.030	"	=	603 "

Deflection of Gal. is practically proportional to the current.
The average deflection taken from the above straight line curve is 107 mm. for .005 amps.
Therefore if gal. is not shunted it will be deflected 107 mm. by .005 ÷ 253 = .0000197 amps.
One millimeter of the scale will then represent .0000193 amps.

(over)

9/12/07.

When shunts are used with the galvanometer, this value must be multiplied by a constant found by the following formula:-

$$\frac{\text{Gal. R}}{\text{Shunt R}} + 1 = \text{Constant.}$$

The Resistance and Constants for the various shunts we have are as follows:-

Shunt marked "Electric Mfg. Co. Troy N.Y."

R Mag in $\frac{1}{9}$ = 33.7 ω. Constant = 1.284

" " $\frac{1}{99}$ = 30.8 " " = 4.113

" " $\frac{1}{999}$ = 3.05 " " = 37.13

"Elliot Bros., London."

R Mag in $\frac{1}{9}$ = 73.9 ω. Constant = 1.345

" " $\frac{1}{99}$ = 66.5 " " = 4.989

" " $\frac{1}{999}$ = 6.55 " " = 39.47

"J. Carpentier, Paris."

R Mag in $\frac{1}{9}$ = 75.6 ω.

" " $\frac{1}{99}$ = 7.33 "

This "Electric Mfg. Co." shunt is the one used in all tests to date.

$\frac{1}{9}$ and $\frac{1}{99}$ coils in 11 = 7.4 ω, Constant 4.405

$\frac{1}{9}$ and $\frac{1}{99}$ coils in 11 = 60.94 ω, Constant 4.135

September 13, 1907.

Sample #1: Carbon.
Gap between 3rd and positive.
Submitted with 60.94 Ω.

Volts.	Amps.	MM. Def.	Amps. x 10⁴	Test #7.
94	.438	5	4	
100.7	.480	14	11	
106.9	.519	34	29	
111.7	.547	63	50	
115.8	.572	101	81	
121.9	.611	185	148	
125.1	.633	263	210	
128.7	.653	326	260	
132.2	.681	417	329	
134	.691	461	370	
136.9	.711	525	419	
139	.727	584	466	
142	.749	630	503	

Vacuum here was about 29.9 inches of mercury.

September 14, 1907.

Samp^le 1. Carbon.

After admitting air and then reexhausting as high as possible on a mercury pump, got between 3^rd electrode + pointing

Test #3.

First tried lamp at 130 V. with different shunts on galvanometer to find which one was suitable. At this P.D., with a 6.55 w shunt, gal. was deflected 630 mm. This is equivalent to .00479 amps. Then after a few minutes tried lamp at 140 V. using a 3.61 w shunt and deflection was only about 100 mm. which is equivalent to .00139 amps. The current was very unsteady and galvanometer kept oscillating rapidly.

Now tried with 6.55 w shunt again, at 140 V. Deflection was about 150 mm. (=.00114 amps)

but at intervals of about two seconds, galvanometer would suddenly swing up off the scale momentarily, and then drop back to 150 mm. These oscillations could also be observed in the milammeter if being in series with both the main current which was lighting the lamps and the shunted "Edison Effect" current — and when the galvanometer connection between the 3rd electrode and positive was broken they disappeared, showing that the vacuum current was the cause of the oscillations rather than variations in the voltage of the line.

On opening the circuit for a short time and then closing again the oscillations would some-

times disappear and after a while the deflection, at 140 V. across the lamp, became quite constant.

Galvanometer was then connected with a 36.47 Ω shunt and the following readings taken:—

Volts.	Amps.	MM Def. = Amps. X 10^6	
100.2	.472	11	17
108	.520	32	49
114	.559	75	114
120.5	.601	156	237
125	.630	228	346
131	.670	325	494
134.5	.694	398	605
139.2	.728	510	775
142	.746	648	985

Gal. between 3rd and negative.

142	.746	0	

Vacuum here was about 29.9 inches of mercury.

September 16, 1907.

Sample #3. Tungsten.

After admitting air and then readmitting to as high vacuum as possible on a mercury pump.

Gal. between 3rd electrode and positive - not shunted.

Test #3.

Volts.	MM Def.	= Amps x 10^7
6.5	5.5	11
7.5	21	40
8.5	40	77
9.3	56	108
10.1	72	139
10.9	89	172
11.7	105	202
12.5	123	237
13	134	258
13.5	148	285
14	161	311
14.5	176	339
15	190	367

Was carrying lamp out of room, holding it gently in my hand, when suddenly it exploded.

September 17, 1907.

Lamp #1. Carbon 116 V.

Recalibrated a second time on the mercury pump. to .28 mm. vacuum.

Gal. between 3rd electrode and positive.

Shunt = 887 Ω.

Test #9.

At 145.2 V. lamp took .502 amps. and gal. was deflected 150 mm. which is equivalent to $.37 \times 10^{-6}$ amps.

Lamp was kept burning at this voltage and deflection of gal. kept diminishing. After 3 minutes lamp at 145 V. took .472 amps. and gal. was deflected 80 mm = $.20 \times 10^{-6}$ amps.

Vacuum is too low. Lamp bulb gets very hot and filament is only at brightest red at 145 volts. Believe it should be white.

September 17, 1907.

Sample #2. Carbon - 113 ± V.
Galvanometer between steel
electrode and platinum.
S. emf = 36.47 v.

Volts	Amps.	MM Def.	Amps x 10⁶	Test #6.
93.1	.448	7	11	
100.4	.493	17	26	
108.2	.543	43	65	
113.9	.582	73	111	
120.7	.627	136	207	
124.9	.657	200	304	
128	.679	246	374	
133	.712	335	509	
136.2	.737	370	562	
140	.760	420	638	
143.5	.787	453	688	

Opl. bitumen 3M and negative

143.5	.787	0		

September 19, 1907.

Samp. #7. Carbon 113 ± V.
After recirculating on mercury pump to practically 100 % vacuum = 761 mm of mercury with barometer at 761 mm also. Gap between 3 rd electrode and positive.
Shunt 3.61 ω

Volts	Amps.	Number = Milliamps.		Test #7.
136	730	380	5.197	
"	"	760	3.553	After ± min burning
"	"	460	6.285	" 7 " "
136.5	734	395	5.174	" 5 " "

Opened circuit momentarily and on closing again gap oscillated between 150 and 310 mm. Oscillating gave more rapid and their amplitude diminished. After about 3 minutes got to 200 - 260 mm.
Opened circuit momentarily again and on closing gap oscillated between 160 and 240 mm.
Broke circuit several times

9/19/07

more after this but each time on remaking galvanometer oscillated the same - between 140 and 200 mm. deflection.

Power was off 1 hour at noon and lamp stood cold for that time. Then at 135.5 volts and .773 amps. deflection of gal. was 59 mm. After lamp had burned about 1 min., gal started to oscillate again - very slowly at first and with increasing speed - between 50 and 160 mm.

Tested them as follows -

Volts	Amps.	MM DEF.	Amps X10⁶	Shunt = 36.47 Ω
95.6	.440	4	6	
102.1	.500	14	21	
109.5	.537	33	50	
112.2	.568	64	97	
117.4	.602	113	172	
123.1	.640	200	305	
126.8	.664	271	413	
133.6	.711	421	642	Gal. did not
137.3	.739	515	790	oscillate during
141.9	.767	645	983	this test!

9/19/07.

Sample #2. Carbon 113 ½ V.

Readjusted a second time to 7.58 mm with barometer at 760 = 99.73 m/o vacuum. Gal. between 3rd + positive.

Volts	Amps.	mm Def.	Amps x 10^6	Test #8.
1427.3	.711	470	6472	- 3.61 w Schmidt

Deflection gradually increased and went off scale (4.50 mm) in about ½ min. Then changed about to 1.906 ohms and kept lamp luminous at 142 volts for a few minutes to note variations of gal. Found that the current did not fluctuate as in Test #7, but it would very slowly increase and then diminish in value while potential of lamp remained practically constant. Took readings at the maximum and minimum points as follows -

1 1427	.713	580	15777	
"	.710	430	11660	
1426.2	.703	640	17354	(over)

9/29/07

Samp #2. Test #8, cont'd.

Then made the following test at different voltages —

Volts	Amps	MM Def. = Amps x 10⁴		
97	.1421	0	—	1.806 w Shunt
103.9	.1460	0	—	
110	.1498	5	.135	
114.2	.1522	12	.325	
119.1	.1552	25	.678	
125.7	.1593	58	1573	
130	.1620	106	2.874	
133.1	.1639	162	4.393	
136.9	.1663	215	5.830	
140.3	.1689	309	8.374	
141.6	.1697	360	9.767	

Kept lamp burning at this voltage for about 5 minutes and deflection remained constant.

Connected small Zn/Hg/Cu cells in series with galvanometer so as to oppose flow of current thru voltmeter. Started tests 50 of these cells to bring gal. back to zero.

September 20, 1907.

Samp# 2. Carbon 113 ± V.
Recalibrated 3rd time to 753 mm. with barometer at 757 = 99.47 % vacuum.
Gal. between 3rd and positive Shunt = 1.806 Ω.

Volts.	Amps.	MM Def.	Amps x 10^6	Jan 31st '09.
140.7	.579	190	5152	
120	.452	2	54	
122.2	.467	18	488	
126	.488	39	1059	
128.2	.500	52	1410	
131	.513	79	2142	
133	.522	98	2657	
136.3	.540	131	3552	
140	.562	195	5287	
142.1	.574	247	6697	
145.8	.597	326	8840	② x

Deflections were fairly constant. Galvanometer did not oscillate.

(over)

9/20/07.

Notes on Test #9 of Lamp #2.

In this lamp a blue glow can be seen very easily, at the negative side of the filament. It diminishes in brightness from the end upwards and disappears entirely before reaching the curved part. It can be seen to the best advantage by looking along the filament from the tip end of the lamp. When viewed from this position it will be seen that the glow is emitted equally from all sides of the filament and extends outward about ½ or 3 millimeters.

When the 3rd electrode and positive lead are connected thru a low resistance shunt as in the preceding test, the 3rd electrode appears to get quite hot so that it glows dull red.

(OVER)

9/20/07.

Notes Continued.

If the 3rd electrode is disconnected from the positive a curious phenomenon is observed. - Immediately there appears a bright blue glow at the positive side - but only around the cemented joint and the exposed part of the platinum sealing in wire. This glow has very much the appearance of a CO flame and every now and then a tongue darts out in the direction of the negative. It is easy to conceive that if the lamps were heated up still brighter this tongue would finally reach across to the other side, forming an arc and fusing the platinum wires - as is sometimes done.

September 21, 1907.

Soimp #2. Carbon 113± V.
Reexhausted 4th time to 748
mm. when barometer stood
at 754 = 99.2 % vacuum.
Opl. between 3rd and positive.

Volts	Amps.	MM Def.	= Amps X 10⁶	Test #10.
142.2	.510	280	427	36.47 w Shunt
142.3	.513	340	2244	8.05 w " -mt mm
143	.518	470	2930	" " " 3 "
110	.359	0	0	8.05 w Shunt
116	.387	1	6	
122	.412	5	31	
127.2	.440	14	87	
130.7	.454	66	411	
132.8	.465	103	642	
134.9	.477	150	935	
137.6	.490	238	1484	
141	.508	388	2419	
143.9	.521	530	3304	② v.
"	.522	650	4052	After running 2 mm
144.3	.540	340	7097	2.33 w Shunt
145.2	.532	255	5322	

September 25, 1907.

Samp^{le} 4. Carbon 113 V.
Galvanometer between 3rd
electrode and positive.

Volts.	Amps	MM Def.	Amps. X 10^6	Test #1.
135.5	.723	610	930	36.47 Ω Shunt
137	.732	580	884	After 5 min. Burn.
89.5	.422	22	46	25.6 Ω Shunt
95.3	.459	27	56	
102.2	.502	36	75	
106	.528	46	96	
111.2	.562	67	140	
116.8	.598	106	222	
123.3	.641	190	397	
127.8	.671	256	535	
132.9	.708	352	736	
135.5	.727	412	862	
139.1	.750	475	994	
143.8	.785	536	1121	

Opened lamp and put in a globule of mercury. Then re-exhausted on Sprengel's pump

9/25/07.

Samp# 4 cont'd.

to 100 m/m vacuum. Then supported lamp vertically so that the mercury was in the socket end - which keeps comparatively cool - and tested as follows:-

Volts	Amps.	MM DEF.	Amps X 10⁶	Test #2.
127.8	.1472	197	6624	1.417 w Schmidt
128	.1476	245	8457	After 5 min. Burn.
97.2	.1491	3	103	
104.5	.1517	10	345	
117.1	.1568	32	1104	
119.3	.1600	71	2449	
125	.1653	163	5623	
130.6	.1698	310	10695	
135	.1730	490	16905	
137.8	.1750	630	21735	

On this test the whole lamp was filled with a pale blue glow which did not seem to be any fluorescence

9/26/07.

Samp# 4 cont'd.

around the negative leg. There was no other else. Globules of mercury condensed on the glass at the bottom, while it was cool.

Substituted a milammeter for the galvanometer - between the third electrode and positive and tested at higher voltages as follows:-

Volts.	Amps.	Milamps.	Test #3.
125.7	.660	6	Samp vertical
130	.697	10	as before.
134.9	.630	17	
137.2	.750	23	
141	.781	32	
144.7	.819	42	
149.7	.848	61	
130	—	10	Samp laid down
135	—	17	so that Hg was
141	—	31	near hot filament
149.3	—	62	

(over)

9/25/07.

Samp# 4 cont'd.

Kept burning a few minutes at 147 volts until suddenly it arced from the 3rd electrode to the negative. The current at this moment must have been pretty high because the middle of the milammeter was bent considerably. The arc also fused the platinum leading-in wires and the copper connecting wires for a short distance down and copper was plated on the bulb at two spots opposite the terminals. The glass support too, was fused considerably and the bulb was also, at the spot nearest the copper was plated. The middle bulb was blackened with carbon.

September 27, 1909.

Samp^e 5. Carbon - 116 V.
A square of tinfoil is shellacced on one side of the exterior of the bulb. Samp also has the usual internal electrode of platinum.

Ot 146.8 V., lamp took .777 amps and "3-2" deflection was 155 mm. using on 9.05 w shunt. = 9.46 X 10^-6 amps. This was with the galvanometer connected between the internal 3rd electrode and the positive.

Now tried using the external tinfoil electrode in place of the platinum 3rd electrode and found there was no deflection whatever either with gal. between tinfoil and positive or tinfoil and negative.

9/27/07.

Samp# 5. Carbon 116 V.

Introduced a globule of Hg into lamp and exhausted to about 99.93 % vacuum. Still could get no current between either positive or negative and the external electrode. Connected gob between internal platinum electrode and positive and tested as follows:

Volts	Amps.	MM per. = Amps. X 10^3		Test # 2
141.7	.750	605	20892	Shunt 1419 Ω
97	.1449	1	34	
104.1	.1493	5	172	
110.7	.533	16	552	
118.9	.588	48	1056	
124.3	.672	92	3174	
129.9	.660	148	5096	
133.8	.1439	272	9384	
137	.1417	402	13869	
140.5	.1340	560	19320	
	Gob between 3rd and negative			
138	.1720	302	7240	Shunt 80.9 Ω

September 28, 1907.

Samp. #3. Immersion.
Introduced cylinder of Hg and exhausted lamp to 100 m.m. vac.
Gal. between 3rd and frontline.

Volts	MM. Def.	Amps. X 10⁶	Test #3.
4.11	5	.9	No Schmidt.
7.00	9	2.0	
8.00	25	5	
9.00	47	9	
10.00	68	13	
11.00	91	17	
12.00	116	22	
13.00	155	30	
14.00	52	41	80.8 w Schmidt
	Gal. frontline and delicate		
	swamp, swung off of scale after		
	lamp had been burning a-		
	bout one minute. Plunged		
	in longer & shunt and reading		
	then was -		
14.00	190	1122	8.05 w Schmidt
	Deflection kept increasing		
After	about 1 min. more it was -		
14.00	320	1995	

9/28/07.

Samp# 3 – Test# 3, cont'd.

Allowed lamp to cool down and then tried at 14 volts again, using 3.05 m ohms.

The deflection at first was 6 mm. ($= 37 \times 10^{-6}$ amps) but after about a minute burning it suddenly went up as before to 135 mm. ($= 841 \times 10^{-6}$ amps) and then kept increasing slowly to still higher values. Do not know what the limit of this increase would have been because I was afraid it might arc and so opened the switch at about 400 mm deflection ($= 2493 \times 10^{-6}$ amps.)

No deflection could be observed with the unshunted galvanometer between the 3rd electrode and the negative.

Samp allowed the bulb glow when burning at 14 volts.

October 5, 1907.

Sample #3. Tungsten.
Recalibrated to 99.89 % vacuum
with Hg. Still in the bulb.
Opal between 3rd and positive.

Volts	MM Def.	Amps. X10⁶	Test #4.
6.00	0	0	No Sensit
7.00	3	.6	
8.00	19	3.6	
9.00	40	8	
10.00	62	12	
11.00	83	16	
12.00	105	20	
13.00	132	25	
14.00	174	33	Burned 3 min. at this P.D. and "Z Z" was constant
15.00	250	48	"Z Z" constant during 3 min. burning.

October 7, 1907.

Samp.# 2. Carbon.
Exhausted, then filled with Hydrogen and reexhausted to 100 o/o vacuum on Hg pump & gal. between 3rd & 4th time.

Volts	Amps.	MM. Defl = Amps x 10^6.		Test # 11.
141.5	.520	350	4781	3.61. W Schmidt
142	.524	330	4508	3m 3 min.
115	.309	7	95	
121.5	.427	27	369	
129.8	.463	78	1065	
135.7	.493	160	2185	
141.5	.522	297	4057	
143.8	.532	370	5054	
148	.557	520	7103	

Galvanometer Shunts – Constants etc.

OHMS		CONSTANT	1 MM. EQUIV. AMPS. X 10^9
∞	—	0	193
2.33	D.C. $\frac{1}{10}$	103.15	20.593
3.61	6.55 ‖ 9.05	70.9	13.664
6.55	3.8 mm. $\frac{1}{100}$	39.47	
9.05	3.2 m.c. $\frac{1}{1000}$	32.3	6.234
18.48	25.6 ‖ 66.5		
25.6	D.C. $\frac{1}{100}$	10.84	2.092
36.47	66.5 ‖ 80.8	7.9	1.525
60.94	66.5 ‖ 729	4.135	
66.5	3.8 mm. $\frac{1}{1000}$	4.089	
74	80.8 ‖ 887	4.405	
80.8	3.2 m.c. $\frac{1}{1000}$	4.118	795
420	729 ‖ 887		
729	3.8 mm. $\frac{1}{1000}$	1.345	
887	3.2 m.c. $\frac{1}{1000}$	1.284	
∞	Still	7.53	
1.718	2.33 ‖ 6.55		
1.806	2.33 ‖ 9.05	140.5	27.116
1.417	2.33 ‖ 6.55 ‖ 9.05	179.8	34.509